HRCM 8:
East Delta ROA Tidal Marsh & Shallow Subtidal Restoration

Incomplete Working Draft
Scientific Evaluation Worksheet

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Restoration Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache HRCM 4evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA.

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Action:

HRCM8: East Delta ROA Tidal Marsh & Shallow Subtidal Restoration

Restore 1,300 acres to tidal action and vegetated tidal marsh and 300 acres of shallow subtidal habitats on portions of Canal Tract, Terminus Tract, and Bract Tract in the East Delta ROA (see Figure 1, below).

Evaluation Team: Tidal Marsh Workgroup

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Approach

1. Construct levees to isolate deeply subsided lands and protect property.
2. Plant tules or place fill material to raise elevations of shallowly subsided lands.
3. Create channels and/or berms to encourage the development of dendritic tidal channels.
4. Breach levees to reintroduce tidal exchange to leveed lands.
5. The canal levees of the eastern alignment of an around-Delta conveyance facility may be incorporated into the design of intertidal emergent wetland restoration. For example, in locations where the conveyance canal is located at elevations at or below elevations suitable for restoration of intertidal marsh, marsh may be restored to the east of canal levee, with the canal levee forming the western boundary of the restored marsh.

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Sacramento splittail and San Joaquin Chinook salmon and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.
4. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The drivers and outcomes discussed in this worksheet are described in the following DRERIP conceptual models: Temperature, Delta smelt, Foodweb, Tidal marsh, Corbicula, Sediment, and Mercury. The references listed at the end of this document provide additional information.

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would occur on Terminus Tract, Bract Tract, and Canal Tract.

Added by Evaluation Team

1. Restoring tidal marsh habitat on the different tracts of the East Delta ROA will have varying levels of both positive and negative effects. For example, some of tracts may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome. Differences in hydrology, topography, soils, and land-use history will also manifest as distinctions in success of this action among the tracts. BDCP's estimated extent of restoration types based upon elevation for each sub-area is presented in Appendices C and D.

2. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low (Schoellhamer et. al., 2007).

3. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs. Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal. This assumption also includes a time limit to allow for subsidence reversal so that restoration of an entire parcel is not delayed indefinitely. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.

4. Source of fill material will be identified and use of all material, including dredge spoils, will be approved by the RWQCB.

5. Tidal water would travel through Sycamore Slough.

6. Water output from the site, post-restoration, will meet water quality standards.

7. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be completed.

Problem(s) with Action as Written:

1. Since rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the Intended Outcomes 1 and 2 (tidal marsh, rearing habitat, and local food) into one outcome.

2. Existing sloughs in the East Delta ROA are currently infested with aquatic weeds and function as a “biological desert”. Remediation of this existing situation is not described in this action.

3. Fish will need to traverse the lower reaches of barren Hog and Sycamore sloughs.

4. This area’s very poor exchange rates with the broader Delta will likely offer little benefit for exported production.

5. Loading of fill material on top of a shallow island may compress the underlying soils. This approach may not yield the intended result. A close study of existing soil conditions including analysis of the local soil map is needed to further evaluate this issue.

6. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, restoration sites below vegetation elevations will function as shallow subtidal habitat.

7. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal range and just into shallow sub tidal elevations (Brown 2003, Simenstad et. al., 2000 as cited in Schoellhamer et. al., 2007, p.26).

Scale of Action:

Small

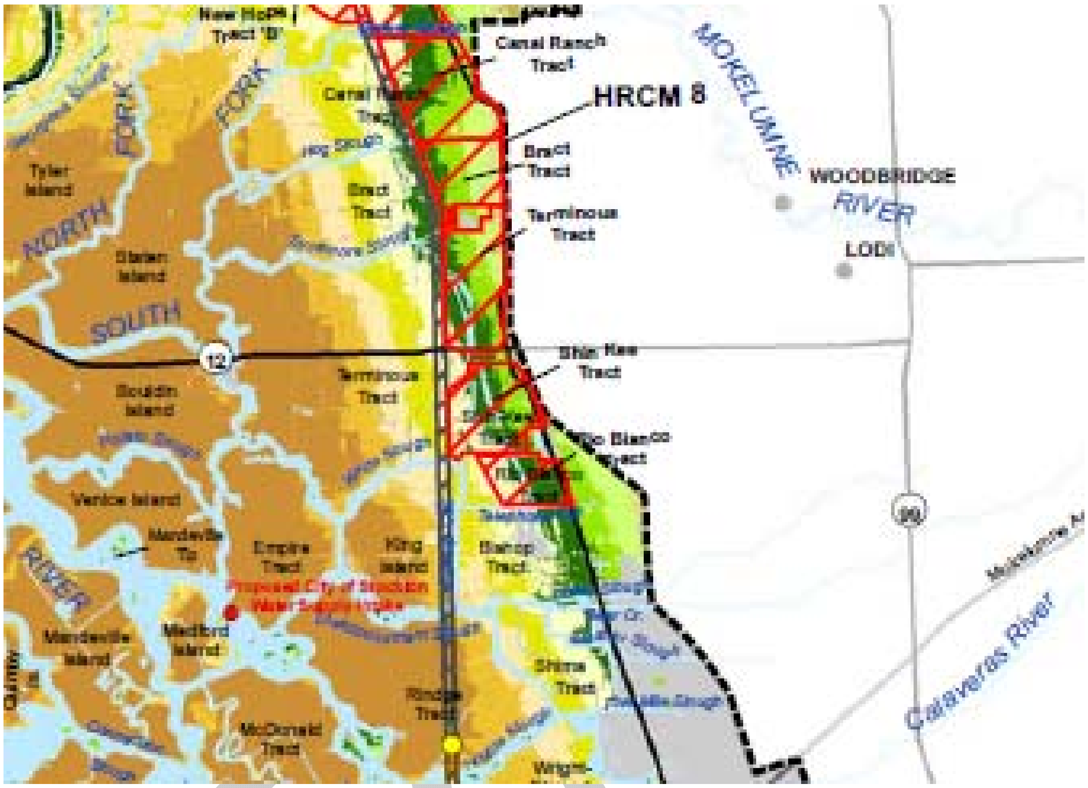
Rationale:

This is a small scale restoration action due to its limited spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally, 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 1,300 of tidal marsh plus 300 acres of shallow sub-tidal restoration options would increase marsh acreage 6% above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 1. Summary of Tidal Marsh Acreages

Area	**Acreage**	**Source**
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed East Delta tidal restoration (this action)	1,300 tidal marsh 300 sub-tidal	BDCP, 2009

Figure 1. East Delta Restoration Opportunity Areas



Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Note: Negative outcomes are scored relative to baseline conditions. These negative mechanisms may also decrease the certainty that positive effects of site restoration will be realized. Appendix "A" contains the above information in summary tables that are organized by the numerical order of the outcomes, rather than species.

Outcomes with Zero Magnitude

During the Evaluation process, several of the outcomes identified by BDCP early in the process, were found to have a zero magnitude. These outcomes are listed below and their evaluation is provided in Appendix B.

- OP1. Increase rearing habitat area (including physical and biotic attributes) for longfin smelt
- OP2. Increase rearing habitat area (including physical and biotic attributes) for Delta smelt
- OP3. Increase rearing habitat area (including physical and biotic attributes) for steelhead.
- OP4a: Locally provide areas of cool water refugia for winter-run salmon.
- OP4b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the tidal marsh team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticides for mosquito control.
- ON2: Increase in the availability of selenium
- ON3: Resuspension and export of contaminants to downstream areas effects on non-covered wildlife species

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No

Nature of Change:

This small scale action to restore 1,300 acres of tidal marsh and 300 acres of shallow subtidal habitat may change the environment on a local scale but not to such an extent that our current understanding of boundary conditions (Harrell et al 2008), hydrodynamics, and ecological processes in the Delta would change.

Overview of Productivity Import-Export

The Cache Slough evaluation worksheet (HRCM4) provides a complete discussion of productivity levels, import and export. Here we describe how conditions may differ from Cache Slough in order to provide the Conservation Measure evaluation appropriate specificity.

- East Delta has less tidal exchange (compared to Cache) due to geographic location (farther away from a river channel etc).
- The small area to be restored in East Delta ROA may result in less primary production (compared to Cache).
- May experience increased primary production compared to other restoration sites because its easterly location offers warmer spring and summer temperatures. However, the scale of the action is small in size and it is highly uncertain whether any of this production will be exported or will benefit covered fish species.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.

As indicated at the beginning of this worksheet under the section entitled “Problems with Action”, the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15. Please note that green and white sturgeon are not known to utilize the Cosumnes and Molkemne River systems and so these species are not listed in the analysis below.

P1a. San Joaquin River/eastside Fall-run Chinook salmon & steelhead

General Observations: Fall-run juveniles move through the Delta from in the winter and spring (Williams and Rosenfield, In preparation, figure 3 and see also page 15 that shows the value of estuarine rearing varies across runs). Tidal exchange in some of these marshes will be hard to accomplish and residence times in the channels leading to the Marsh will be high. This will expose emigrating salmon and steelhead to poor habitat conditions for extended periods and delay successful emigration.

Magnitude = 2 - Low
Outcome assumes that “rearing habitat area” (quantity) and/or food is limiting. Page 16 of Williams and Rosenfield, In preparation, states that “Fall Chinook […] could benefit strongly from tidal marsh restoration”. Fall Chinook generally enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities. Fall run will eat the types of food produced in this habitat.

San Joaquin River and eastside fall-run migrate through this area from January and into June, with a pulse in May ((Williams and Rosenfield, In preparation) Figure 3). High temperatures are probably common in this area during May (as indicated by IEP gauges in the lower San Joaquin River, rsan 007 and rsan058). Average daily temperatures exceed 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 and see Richter and Kolmes 2005) during May in many years. In June, average daily temperatures probably exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Steelhead rearing in this proposed restoration site during May and June will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The limited scale of this restoration proposal, the small number of fall-run likely to rear in this area, and the relative isolation of the proposed restoration sites from migratory corridors make the likely magnitude of this outcome undetectable. Benefits to some rearing Chinook salmon may be largely offset by negative temperature effects to later rearing steelhead.

Certainty = 2-Low
Because of the small scale of this project, its relative isolation from salmon migratory corridors, the high temperatures that are likely to persist through a large portion of the rearing season and the many other factors limiting fall run production in the San Joaquin River, it is moderately certain that the positive magnitude of this action will be minimal at best.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1b. Splittail

General Observations: The relationship between the drivers and outcomes is described in Kratville, 2008 on pages P1h Pg 12, 13, 14, 15.

Magnitude = 2 Low
While more tidal marsh will help rearing of juvenile splittail, the expected benefit to the overall population is medium. Sacramento splittail population abundance is limited by the lack of floodplain inundation to provide spawning habitat. When large scale inundation occurs, splittail population abundance is high for several years following the inundation event. Long periods without floodplain inundation results in reduced splittail population abundance. Splittail do not appear to be habitat limited at other life history stages.

Certainty = 3 - Medium
Whether the proposed restored rearing habitats will result in increased splittail population abundance is not certain. Although the restored habitat will increase the opportunity for rearing juveniles to feed during their downstream migration, tidal marsh does not appear to be a limiting factor in splittail abundance compared to floodplain inundation. The bulk of the adult splittail population resides in the brackish areas of Suisun Marsh. It is anticipated that most of the restored marsh in this ROA will be freshwater and so will only provide habitat for juvenile fish migrating into Suisun Marsh. This restoration may not provide a new population center or increase the numbers making it to Suisun Marsh. The restoration site is not located directly downstream of a floodplain and so its use by out-migrating fish may be limited.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to splittail. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1c. Green Sturgeon

General Observations: The basic relationship between drivers and outcomes is described in Israel and Klimley, 2008, pages P1i Pg 4, 8, and 9.

Magnitude = 2 - Low
Information on green sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon located in other systems do feed on drifting insects (Radtke 1967 and McCabe, G et al. 1993). This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary. Soft bottom benthos are a food resource for the sturgeon. Most habitat limitations for green sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009. It is unknown to what extent adult sturgeon used freshwater tidal marsh for foraging. The impact to individual sturgeon may be low but the extreme loss of freshwater tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Certainty = 2- Low
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

P1d. White Sturgeon

General Observations: The basic relationship linking drivers to outcomes is described in pages 1j, 19, 20, and 21 in the DRERIP White sturgeon model (Israel et. al., 2009).

Magnitude = 2 -Low
Information on white sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon (located in other systems) do feed on drifting insects. . This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary so benthic food items are expected to be limited in this restoration (Siegel, personal communication, Feb. 2009). Habitat limitations for white sturgeon appear to occur upstream and downstream of the restoration area (i.e. outside the ROA).

Certainty = 1 - Minimal
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

Outcome P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the eastern and central Delta.

P2a. All covered fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009. Please see the evaluation worksheet for action # HRCM4-Cache/Yolo, Outcome P3, for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled “Research Needs”.

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology

Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1-2 Minimal to Low
The implied relationship is that restored tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = 1 - Minimal
The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web

production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative.

Outcome P3: Provide local areas of cool water refugia for Delta smelt and salmonids

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the landscape scale (medium) of the action, the relationship between tides, physiography, and water temperature could be moderate. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008).

For more details, please see the introductory text in the HRCM 4- Cache Slough action worksheet and the Suisun Marsh Tidal Marsh Restoration Worksheet, specifically, Outcome P4.

P3a: Delta smelt

Magnitude: 2 - Low
The spatial extent of cool water refugia could be relatively limited. However, in some cases a large effect could be felt across relatively large area across the range. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty: 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted.. Please refer to text in outcome P4 of HCM4 – Cache/Yolo Restoration Action Outcome P4, page 27 for more details.

P3b. Salmonids

High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright pers. comm.). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, Chinook salmon (spring-run and fall-run) and steelhead rearing in this proposed restoration site during June and July will probably be impacted by high temperatures. Forces that reduce those temperatures may improve survival, growth and smoltification success.

Benefits are limited to those emigrants rearing in this habitat after May, when temperatures in this region increase above optimal rearing threshold of 12-16^{o}C (Marine and Cech 2004). These benefits are expected to be transient (on annual and decadal time scales) and will never effect more than a small fraction of populations for any of the covered species (unless there is a cumulative impact from numerous restoration that produce the same cooling effect. Also, as mentioned in the description, this phenomenon is transient over time as the timing of tidal cycle shifts. Complexity of thermodynamics in conjunction with local geomorphology and long-term climate change and sea level rise introduce considerable uncertainty.

In addition to the runs listed below, please see Appendix B for winter-run etc.

P3b1: Spring run salmon

Magnitude = 2- Low.
This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area.

Certainty = 1-Minimal

Certainty is minimal for reasons similar to that described in P3a, above. This outcome is highly dependent upon highly variable ecosystem processes. Although scientists have a reasonable understanding at the general level, the range of data needed to evaluate at the action scale is lacking.

P3b2: Fall run salmon

Magnitude = 2- Low
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. The scores below for N1a to N1d do not represent the potential to distract detract from the positive benefits of the action because these deductions were considered i by reducing the certainty scores for positive outcome # P1. Where appropriate, the impacts associated with the establishment of harmful invasive species on the restored marsh are discussed below.

N1a: Submerged Aquatic Vegetation (SAV) (including *Egeria*)

General Observations: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome.

The basic relationship between drivers and outcomes is described in the DRERIP aquatic vegetation conceptual model on pages 8, 9 10 and Figure 2 (Anderson, In preparation). Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium
The establishment of SAV in general is controlled by local flow conditions and substrates. Local flow conditions control many aspects of SAV physiology, most importantly in this area turbidity. In nearby Liberty Island where turbidities are generally higher due to wind wave action, SAV is restricted to shallow near shore areas (Ustin et al. 2008). If turbidities are high in the restoration area, then SAV establishment and growth may be reduced to levels similar to Liberty Island. If not, there is the potential for SAV amounts similar to Franks Tract. The substrates in this area would be expected to support establishment of SAV (Anderson, In preparation). Small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV and therefore the net effect is medium.

For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The restoration of a tidal marsh that eventually becomes infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation).

Eventually, the clarity of water entering the site from upstream will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action will worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species.

Certainty = 2 - Low
There is high uncertainty about the initial colonization and ultimate patch distribution of SAV on the substrate. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model). It is well documented that the physical structure of SAV facilities slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood (Anderson, In Preparation).. The uncertainty of this outcome is largely dependent on how the final marsh system functions (Anderson 2007). Future changes to water salinity in the eastern Delta may affect the certainty score related to this outcome.

N1b: Non-native Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1. The relationship among drivers and outcomes is described in Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005).

Magnitude = 4 - High
For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish.

The establishment of Centrarchids in conjunction with SAV is well documented, especially in this portion of the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of Centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into suitable habitat areas of the restored system. The extent of their impact on the native ecology of the restored marsh is partially dependent on the extent of SAV establishment and patch size. It is highly probable that Centrarchid fish will become established in this area as they have everywhere else in the Delta.

Certainty = 3 - Medium
It is highly probable that Centrarchid fish will become established on this restoration site. However, once established, the ultimate size of the centrachid population and their impacts to local native fish are less certain. In areas with low SAV patch size, the numbers of Centrarchid fish and their presumed impact on native fish are lower then where the opposite is true (Brown and Michniuk 2007).

N1c: *Corbicula*

The relationship between drivers and outcomes is described in the DRERIP Corbicula Conceptual Model (Thompson et. al., In revision).

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas and/or consumes the productivity of shallow areas exported to channels to such a high extent that it exhibits top-down trophic control. *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). According to the *Corbicula* model (Thompson et. al., In revision page 11), no local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation. In this case, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh which may also become infested with *Corbicula* at some future time would not represent a significant change above baseline conditions. Establishment of *Corbicula* would however, consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the restoration area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Magnitude: 1- Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels. Corbicula is a significant limiting factor throughout Delta (Thompson et. al., In revision). For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions.

Certainty: 2 - Low

The timing and extent of colonization by *Corbicula* cannot be predicted for specific restoration sites due to lack of data.

Corbicula are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the east Delta restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on these east Delta sites. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides Effects on Delta and Longfin Smelt

General Observations

Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in Suisun Marsh shoreline habitats (Matern et al. 2002), and the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). The Delta smelt model (page 3) includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in the Delta smelt conceptual model pg 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield, 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield, 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with Striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for Inland silversides. However, predator-prey interaction between Delta smelt and Inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that Inland silversides reduce calanoid copepods (Norbriga and Herbold, 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Williams and Rosenfield, In preparation; Israel and Klimley, 2008; Kratville**,** 2008); and Israel et. al., 2009 do not mention inland silversides so this evaluation assumes no adverse effects and focuses its evaluation on Delta smelt and longfin smelt.

Magnitude = 2 (low)
Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species who lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding

habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 - Low
Understanding of interaction between inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by Inland silversides. Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of Inland silverside predation. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A – covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

N2a: Covered fish species

General Observations: methyl mercury: The relationship between drivers and outcomes is supported by (Alpers et. al., 2008, Table 2 and associated text). Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, (Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular, the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants
Past land use determines risk of other contaminants: lead risk in areas with significant hunting (e.g., pheasant farms or duck clubs). Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past two years, which suggests that if these pesticides were used, allowing for a two year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley and other sources is also a concern, however it was not evaluated in this worksheet..

Magnitude: 1 - Minimal
No toxicological studies have been conducted with any of the covered species regarding acute toxicity. Mercury concentrations in covered fish are compared against concentrations producing mortality in other fish species. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). Tissue data for longfin and Delta smelt was not found. This analysis assumes that both species will have tissue concentrations similar to that of other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). From these facts, one can conclude that, about a 10X safety factor between fish tissue concentrations in the Delta and the values reported to cause mortality in lab studies.

Regarding chronic toxicity, again there are no toxicological studies with any of covered species. Therefore, this analysis compares the reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormone response changes are observed at 0.25-0.27 ppm wet weight (Alpers et. al., 2008, page 30). Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm (Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low
Limited tissue data is available for most covered species and there is a large safety factor regarding acute toxicity.

Limited toxicological data is available for most of the important sub-lethal processes and none of this data has been collected for the species of interest. A very limited tissue data set is available for most of the covered species and this makes it impossible to determine the proportion of population potentially at risk.

N2b: Methyl mercury, non covered species

General Observations: The relationship between drivers and outcomes is described in the DRERIP Mercury Conceptual model (Alpers et. al., 2008, Table 2 and associated text).

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's Terns nest in Delta. However, mercury levels in small fish consumed by terns are higher in parts of the Delta, such as the Yolo Bypass, than in San Francisco Bay. This suggests that other bird species filling the Forster's tern niche in the Delta may be at risk. Mercury contamination may result in possible sustained, minor population effect on large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau *et al*., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2006). Expected sustained minor population effect or effect on large area.

Certainty: 2-3 Low-Med
Scientific understanding of methylmercury effects on some bird and mammal species is high and this is based on peer-reviewed studies from the San Francisco Bay Area and elsewhere outside of the system. However, methylmercury effects on other bird, reptile, and mammal species is unknown. The nature of this outcome is greatly dependent on highly variable ecosystem processes.

N2c: Methyl mercury, Human Health

General Observations: See also results from water quality team.

Magnitude: 2 - Low
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury RfD and could experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). The proposed restoration action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for covered and non-covered species.

Certainty: 3 - Medium
Uncertain magnitude and direction of change in mercury content of sport fish; although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (OEHHA, 2008a,b). It is not known how many anglers would access the project area and what fish they would catch and consume.

Outcome N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids.

N3a: Covered fish species

General Observations: Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is possible. Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years (DPR, 2008). The relationship between drivers and outcomes is described by the DRERIP Pyrethroids conceptual model (Werner and Oram, 2008, Figure 1).

Magnitude: 1-2 – Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species). Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown.

Certainty: 1 - Minimal
The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of outcome greatly dependent on highly variable ecosystem processes affecting fate (degradation) and transport of pesticides.

N3b: Non covered wildlife species

General Observations: The relationship between drivers and outcomes is described in Werner and Oram, 2008, (Figure 1).

Magnitude: 1-2 Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty: 1 - Minimal
The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting fate (degradation) and

transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids).

N4a: Covered fish species

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

General Observations: The relationship between drivers and outcomes is described in Alpers et. al., 2008 (Figures 4, 7, and 8 and associated text) and Werner and Oram, 2008, Figure 1.

Magnitude: 1 - Minimal
The degree of scouring of pre-project soils depends on hydrodynamics. Scour could be a short-term phenomenon as channels reach geomorphic equilibrium.. Potential for increasing methylmercury concentrations in high-elevation marsh (infrequently wetted zone) and possible export of this to downstream environments.

Certainty: 2 - Low
The nature of this outcome is greatly dependent on highly variable ecosystem processes affecting fate (e.g. photodegradation of methylmercury) and transport.

Outcome N5: Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip.)

N5a. San Joaquin Chinook:

General Observations:
The relationship linking drivers and outcomes discussed in this analysis is described by Brown 2003 (and sources cited therein). Rearing and migration are two activities that

juvenile salmonids (and other migratory species) must accomplish to complete their life cycle. These two activities are in a dynamic tension as migration rate and rearing time are somewhat inversely proportional (when juveniles are "rearing" in a habitat, they are not migrating). If migrating salmonid juveniles begin to rear in a habitat that then becomes inhospitable (due to changing temperatures, the appearance of predators, or radically altered hydrodynamics cause by export pumping), the "rearing habitat" may instead become an area of high mortality. Similarly, if migrating juveniles have difficulty exiting habitat to continue their migrations, rearing habitat may delay important transitions from one habitat to the next.

Magnitude = 1 - Minimal.
The geographic location of the proposed restoration site is disconnected from probable migration corridors for San Joaquin River salmon. Salmon may migrate upstream into waterways other than their natal stream (Williams 2006) and so it is possible that emigrating Chinook will move into these “restored” areas. However, temperatures will likely become stressful in these areas towards the end of the migratory period. As a result, in the days and weeks after Chinook salmon migrate into the sloughs and restored wetlands, it is possible that the habitat will degrade (due to rising temperature and declining dissolved oxygen) and that Chinook salmon in these backwater wetlands will find them hard to escape.

Certainty = 3 - Medium
The number of Chinook salmon entering these restoration sites (and the frequency with which this occurs) is difficult to project but is likely to be low (making the certainty of a minimal magnitude moderately certain).

N5b. Steelhead:

General Observations:
The relationship linking the drivers to outcomes discussed in this worksheet are described by Brown 2003 (and sources cited therein).

Magnitude = 1 - Minimal
The geographic location of the restoration site is disconnected from probable migration corridors for steelhead. Steelhead may migrate upstream into waterways other than their natal stream (Williams 2006) and so it is possible that emigrating steelhead will move into these “restored” areas. However, temperatures will likely become stressful in these areas towards the end of the migratory period. As a result, in the days and weeks after steelhead migrate into the sloughs and restored wetlands, it is possible that the habitat will degrade (due to rising temperature and declining DO) and that steelhead juveniles in these backwater wetlands will find them hard to escape.

Certainty = 3 - Medium
The number of steelhead entering these restoration sites (and the frequency with which this occurs) is difficult to project but is likely to be low.

N5c. Delta smelt:

General Observations:
The relationship linking drivers to the outcomes discussed in this worksheet are described by Brown 2003 (and sources cited therein).

Magnitude = 2 - Low
The geographic location of the restoration sites occur on the edge of the Delta smelt's historic range. Still, larval Delta smelt may be dispersed into these marshes and the sloughs that surround them. Temperature and other water quality conditions (see above) are likely to deteriorate towards the end of the spring. Delta smelt may be trapped in these areas – unable to escape deteriorating conditions. Because Delta smelt are expected to occur here only in low numbers and with low frequencies, the ultimate impact of this effect is expected to be small.
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Certainty = 3 - Medium
The low number and frequency of Delta smelt occurrence in this area make it moderately likely that the magnitude of this impact will be low. Under current conditions in the southeast Delta, Delta smelt larvae that enter restored marsh habitats in this area will suffer high mortality rates. This action does not represent a significant change from that baseline condition.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of "residence" times for fish. There is a non-linear relationship between fish "residence time" and the benefit of the rearing habitat as, at high "residence times" new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- Centrarchid models are needed to understand predator-prey-habitat interactions.
- Striped bass model is needed to understand predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- Baseline predation pressure in this region should be better understood.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- Prior to implementation, conduct a complete Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides).
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this site.
- Better data on where and when Delta smelt lay their eggs would better allow assessment of the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.
- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in these habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all Central Valley salmonid populations is unwarranted and could lead to disastrous "restoration" projects. In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for larvae of pelagic fish (like longfin and Delta smelt).
- Future research should generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).
- It would be helpful if future research could generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Evaluate the effectiveness of water management strategies on managed wetlands to reduce the production of low dissolved oxygen events associated with managed wetlands operations and transfer what is learned into best management practices for the broader managed wetlands community in this region. In addition, it is likely the reduction of low DO events will result in

- conditions less favorable for MeHg production and thus reduce MeHg loading to the surrounding aquatic environment. This hypothesis needs testing.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.
- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. The following on-the-ground actions would be needed to reverse this action:
1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regarded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) newly installed levees would need to be removed as necessary
6) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:
1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation,
5) Mitigation planning

Opportunity for Learning

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration as a part of a comprehensive adaptive management program. See text in the Cache Slough (HRCM 4) worksheet for details.

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Appendices

Appendix A: Summary Tables Organized by Outcome

Table 3. Positive Outcomes

Outcome	Magnitude	Certainty
P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.		
a: San Joaquin River/eastside Fall-run Chinook salmon and steelhead.	2	2
b. Splittail	2	3
c. Green Sturgeon	2	2
d. White sturgeon	2	1
P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the eastern and central Delta. (all covered fish species)		
a. Viewpoint #1	3-4	3
b. Viewpoint #2	1-2	1
P3. Locally provide areas of cool water refugia for Delta smelt and salmonids.		
a: Delta smelt.	2	1
b1. Spring-run.	2	1
b2: Fall-run.	2	1
b3: steelhead.	2	1

Table 4. Negative Outcomes

Outcome	Magnitude	Certainty
N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.		
a. SAV.	3	2
b. Non-native Centrarchids	4	3
c. Corbicula.	4	3
d. Inland silversides.	2	2
N2: Potential for mercury methylation and local bioaccumulation to affect wildlife.		
a. Covered fish species	1	2
b. Other species (not covered).	3	2 to 3
c. Human health.	2	3
N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids		
a. Covered fish species.	1 to 2	1
b. Other species (not covered).	1 to 2	1
N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids).		
a. covered fish species.	1	2
N5: Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip.)		
a: San Joaquin Chinook	1	3
b. Steelhead.	1	3
c. Delta smelt	2	3

Appendix B - Outcomes With Zero Magnitude

OP1. Increase rearing habitat area (including physical and biotic attributes) for longfin smelt.

General Observations: Longfin smelt do not occur in this area with any frequency. These fish do not use tidal marsh habitats. The magnitude of this outcome is zero for this species with a certainty of “4”.

Longfin smelt do not occur with any regularity or abundance in this region. Longfin smelt model text indicates: LFS are rarely detected above Rio Vista on the Sacramento River (Wang 1991; and R. Baxter, CDFG, unpublished data). Furthermore, model indicates that, soon after they become free-swimming fish, longfin smelt concentrate in deepwater environments – marsh is not considered “rearing habitat” for longfin smelt.

OP2. Increase rearing habitat area (including physical and biotic attributes) for Delta smelt.

General Observations: Drivers, linkages, and outcomes are described by the DRERIP Delta smelt conceptual model (Norbriga and Herbold, 2008) which states that the food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality. The food web supporting Delta smelt is based on the production of pelagic zooplankton (see page 21 of model). Delta smelt historically spawned in the east Delta in some years (Norbriga and Herbold, 2008, page. 11).

Magnitude: The magnitude is scored as a **zero** because Delta smelt were periodically found in the east Delta historically (Bennett 2005, Figure 1) but they are infrequent or absent from this area in recent years (Norbriga and Herbold, 2008, Figure 3). Delta smelt eat food produced on tidal marshes; but, Delta smelt do not forage in shallow environments (Norbriga and Herbold, 2008, page. 27 and elsewhere, and pers. comm. with B. Herbold, US EPA). Delta smelt will not benefit from the physical habitat structure to be created on shallow parts of this restored landscape. Food consumed *in the shallow tidal areas* is likely to be nil. This outcome assumes that Delta smelt are limited by food production in this area. The food consumed in directly adjacent pelagic habitats depends entirely on how much of the zooplankton produced in the shallow areas is consumed by fish that actually forage in shallow environments where the food is produced. Delta smelt rearing in open water habitats may have, in the past, relied on export of food from a vast network of tidal marshes (Norbriga and Herbold, 2008, page 12). The limited scale of this restoration proposal, the infrequent occurrence of Delta smelt in this area, and the relative isolation of the proposed restoration sites from pelagic habitats and migratory corridors used by later life history stages of Delta smelt make the likely magnitude of this outcome undetectable.

Certainty: Certainty is moderate and is scored as a **3.** The magnitude of outcome is dependent on highly variable ecosystem processes or other external factors. The impact of food produced on site is related to how much of that food makes it into the adjacent channels and bays and to the nature and extent of food limitation in this region currently. These factors are somewhat uncertain. The magnitude of food production depends on physical aspects of the restoration (e.g. those that contribute to retention time) and biological outcomes (e.g. the amount of food consumed in shallow areas that is then not exported to adjacent deep habitats).

OP3. Increase rearing habitat area (including physical and biotic attributes) for Steelhead.

General Observations: Drivers, linkages, and outcomes are described by the DRERIP Salmonid model which indicates that steelhead juveniles move through Delta from Jan-Jun, but mostly from late March-June (Williams and Rosenfield, In preparation, Fig 27 and DLO figure. See also the value of estuarine rearing varies across populations on page 15). Tidal exchange in some of these marshes will be hard to accomplish and residence times in the channels leading to the Marsh will be high. This will expose emigrating salmon and steelhead to poor habitat conditions for extended periods and delay successful emigration.

Magnitude: The magnitude of this action will not be detectable and is scored as a zero. This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting in this area. Page 16 of Williams and Rosenfield, In preparation states "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, <u>and for steelhead</u>." This conceptual model (Estuarine – growth) shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth. In other systems, steelhead use tidal marsh habitat but, the text notes, steelhead smolt in this system are large compared to other systems so research there is not likely to apply here. Steelhead will eat the types of food produced in this habitat. Steelhead migrate past this area "mainly in April and May" (Salmonid model P 34.) High temperatures are probably common in this area during May (as indicated by IEP gauges in the lower San Joaquin River, rsan 007 and rsan058). Average daily temperatures exceed 20-21oC (beyond which sublethal effects accumulate; Reese and Harvey 2002 and see Richter and Kolmes 2005) during May in many years. In June, average daily temperatures probably exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Steelhead rearing in this proposed restoration site during May and June will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The limited scale of this restoration proposal, the infrequent occurrence of steelhead in this area, and the relative isolation of the proposed restoration sites from migratory corridors make the likely magnitude of this outcome undetectable. Benefits to some rearing steelhead may be largely offset by negative temperature effects to later rearing steelhead.

Certainty: Certainty is moderate and scored as a 3. There is no direct research on use of shallow estuarine habitat by steelhead in this system. Any effect will be limited to the San Joaquin population and to those times of year when temperatures are not too high in the target area.

OP4a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP4b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix C: Excerpt From BDCP Steering Committee November 21, 2008, Handouts #2 and #3

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #2

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Estimated Extent of Lands within Restoration Opportunity Areas that may be Suitable for Tidal Marsh Restoration Area by Elevation Class

Note: The acreage values presented in this table that may be suitable for tidal marsh restoration are likely somewhat less than shown because the footprint of roads and other features that might not be removed to accommodate tidal marsh restoration are included in the table. Acreage values shown for the South Delta ROA do not include lands that may also be suitable for floodplain restoration.

Restoration Opportunity Area (ROA)	Area by Elevation Class (acres)										Total
	Upland (>+15 feet)[1]	Transitional Upland 2 (>+3-15 feet)[2]	Transitional Upland 1 (>+3-6 feet)[2]	Sea level Rise Accommoda-tion (>0-+3 feet)[2, 3]	Tidal Marsh[4]	Subtidal 1 (<0-3 feet)[4]	Subtidal 2 (>-3-6 feet)[4]	Subtidal 3 (>-6-9 feet)[4]	Subtidal 4 (>9-12 feet)[4]	Subtidal 5 (>-12 feet)[4]	
East Delta ROA											
Canal Ranch Tract	N/A	133	521	568	714	113	1	0	0	0	2,050
Bract Tract	N/A	212	329	254	273	8	0	0	0	0	1,076
Terminous Tract	N/A	105	216	412	847	131	2	0	0	0	1,713
Shin Kee Tract	N/A	7	60	422	625	344	134	14	1	1	1,608
Rio Blanco Tract	N/A	1	3	69	399	200	151	20	0	0	843
Subtotal	N/A	458	1,129	1,725	2,858	796	288	34	1	1	7,290

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #3

PRELIMINARY DRAFT—FOR DISCUSSION ONLY

Potential Opportunities for Tidal Marsh Restoration
by ROA based on Implementability, Suitability, and Cost
(Does not include assessment of covered fish species benefits.)

Restoration Opportunity Area and Land Units	Potential Opportunities for Tidal Marsh Restoration (acres) [1]					
	Very High[2]	High[3]	Moderate[4]	Low[5]	Very Low[6]	Total Potential
East Delta ROA						
Canal Ranch Tract	0	0	0	1,400	0	1,400
Bract Tract	0	0	0	540	0	540
Terminous Tract	0	0	0	1,400	0	1,400
Shin Kee Tract	0	0	0	1,400	130	1,530
Rio Blanco Tract	0	0	0	0	670	670
Subtotal	0	0	0	4,740	800	5,540

Notes:

[1]Cell values above 1,000 acres are rounded to the nearest 100 acres. Cell values below 1,000 acres are rounded to the nearest 10 acres.

[2]Very high = the extent of sea level rise accommodation, tidal marsh, and subtidal 1acreage elevation classes from Handout #2 that achieve >80% of the highest possible Step 2 criteria score from Handout #1.

[3]High = the extent of the subtidal 2 acreage elevation class from Handout #2 that achieves >80% of the highest possible Step 2 criteria score from Handout #1and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >70-80% of the highest possible Step 2 criteria score from Handout #1.

[4]Moderate = the extent of the subtidal 2 acreage elevation class from Handout #2 that achieves >70-80% of the highest possible Step 2 criteria score from Handout #1and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >60-70% of the highest possible Step 2 criteria score from Handout #1.

[5]Low = the extent of the subtidal 2 acreage elevation class from Handout #2 (Table 1) that achieves >60-70% of the highest possible Step 2 criteria score from Handout #1 and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >50-60% of the highest possible Step 2 criteria score from Handout #1.

[6]Very Low = the extent of the subtidal 2 acreage elevation class from Handout #2 (Table 1) that achieves >50-60% of the highest Step 2 criteria score from Handout #1 and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve ≤50% of the highest possible Step 2 criteria score from Handout #1.

[7]Includes upland elevation class acreage shown in Handout #2 for this location that would be excavated to elevations that would support tidal marsh.

			Viewpoint 1		Viewpoint 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Positive Outcomes						
P2a	All	Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.	3-4	3	1-2	1
P3a	Delta Smelt	Locally provide areas of cool water refugia for delta smelt	2	1		
P1a	Fall-run Chinook salmon- San Joaquin River or eastside	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1c	Green Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1b	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	3		
P1d	White Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	4	3		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish.	3	2		
N7a	Chinook salmon- San Joaquin	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N7c	Delta smelt	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	2	3		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N7b	Steelhead	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.